

Effects in Advanced Nanocrystal Nonvolatile Memories  
From Heavy Ion Irradiation

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We have irradiated engineering samples of Freescale 4M nonvolatile memories with heavy ions. The samples are produced as part of the process development, targeted on the 90 nm node. They use Si nanocrystals as the storage element, rather than the more common floating gate. The samples have been more fully described elsewhere [1]. The irradiations were performed using the Texas A&M University cyclotron Single Event Effects Test Facility. The chips were tested in the static mode, and in the dynamic read mode, dynamic write (program) mode, and dynamic erase mode. All the errors observed appeared to be due to single, isolated bits, even in the program and erase modes. These errors appeared to be related to the micro-dose mechanism. That is, the ion deposits positive charges in the oxide, in a small region, but with high density. These positive charges either neutralize the negative charges on the storage element directly, or they create a leakage path, which allows the stored charge to escape. Either way, the result is a threshold voltage shift, which, if it is large enough, causes the cell to be misread. All the errors corresponded to the loss of electrons from a programmed cell. The underlying physical mechanisms will be discussed in more detail in the final paper. There were no errors, which could be attributed to malfunctions of the control circuits. At the highest LET used in the test (85 MeV/mg/cm<sup>2</sup>), however, there appeared to be a failure due to gate rupture. Failure analysis is being conducted to confirm this conclusion. There was no unambiguous evidence of latchup under any test conditions. The test device frequently went into a high current state during the exposure, which could be reversed by cycling the power. But even in the high current state, the device was fully functional, which suggests that the high current was not the result of a general latchup. Generally, the results on the nanocrystal technology compare favorably with results on currently available commercial floating gate technology, indicating that the technology is promising for future space applications, both civilian and military.

1. R. Muralidhar, et al., *A 6V Embedded 90 nm Silicon Nanocrystal Nonvolatile Memory*, IEDM Technical Digest, 2003.

